PHENIX Run13 Local Polarimetry

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One of the most important goals of the PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) is to study the proton spin structure by measuring spin asymmetries during particle production. The Run13 PHENIX experiment collided longitudinally polarized protons at $\sqrt{s}$ = 510 GeV. Helicity asymmetry measurements of various probes from the experiment are ongoing.

RHIC is capable of running polarized proton beams, and each beam polarization P is measured by RHIC polarimeters using left-right asymmetry in elastic scattering in the Coulomb Nuclear Interference (CNI) region. Since the stable beam polarization direction in the RHIC rings is vertical, the beam polarization direction is kept vertical in RHIC except in experimental halls. For each ring, Spin Rotators, which consist of superconducting helical dipole magnets, rotate the beam polarization direction the 90 degrees at the entrance and the exit of the PHENIX experimental hall.

Since beam polarization may not purely be longitudinal at the experimental hall, we require measurements of transverse and longitudinal component of P ($P_\perp$, $P_\parallel$) at the experimental hall, which is local polarimetry, as they introduce systematic error. Local polarimetry is especially important in A_{LL} measurements for studying gluon polarization in a proton since A_{LL} is very small, and $P_\perp$ has potential to introduce significant error.

PHENIX Local Polarimetry uses large transverse single spin asymmetry (left-right asymmetry) A_N of forward neutron production. Left-right asymmetry originates from the interference between spin flip and non-flip amplitudes. One Pion Exchange (OPE) models describe the production cross section of forward neutron reasonably well, but the pion exchange amplitude is fully spin flip.[1)] Theoretical study is still ongoing.

PHENIX Local Polarimeter measures energies and trajectories of forward neutrons. The local polarimeter consists of Zero Degree Calorimeters (ZDCs), and Shower Max Detectors (SMDs). ZDC consists of W-Cu alloys and PMMA (polymethyl methacrylate) based optical fibers, and collects Cherenkov photons produced by charged secondary particles from neutron showers. SMD is an X-Y plastic scintillator strip hodoscope. It is located between the 1st and 2nd ZDC modules, where the approximate hadronic shower is maximum. X-Y position of a neutron is reconstructed by using shower profile on SMD. Those detectors are located 1800 cm away from the collision point, and cover 10 cm x 10 cm of a transverse plane at each zero degree area.

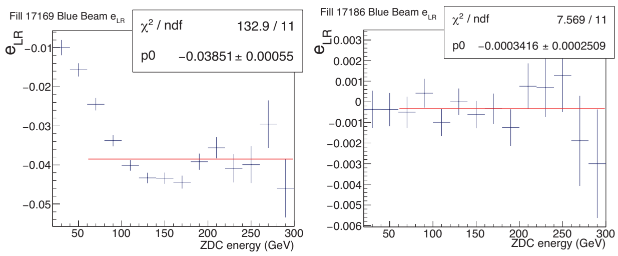

Fig. 1. Observed asymmetry in transverse fill (left), in longitudinal fill (right). The red lines are constant fittings.

The observed left-right asymmetry e_N of forward neutron production is defined as $e_N = P_\perp A_N^{\rm Eff}$, where $A_N^{\rm Eff} = f_{\rm smear} A_N$. $f_{\rm smear}$ is the smearing effect, correlated to the neutron energy-dependent position resolution[1)]. $f_{\rm smear}$ is assumed to be constant during the Run13 experiment.We measure $A_N^{\rm Eff}$ at transversely polarized proton beam collisions, where $P_\perp = P$ so that it is measured by RHIC polarimeters. After that, we measure e_N with the local polarimeter to obtain $P_\perp$ of longitudinally polarized beams.

Fig.1 shows e_N plots. The left (right) plot shows e_N of transversely (longitudinally) polarized proton beam collisions.

As a final result, $\frac{P_\perp^Y}{P^Y}\frac{P_\perp^B}{P^B}$ is $\sim O(10^{-3})$ and $\frac{P_\parallel^Y}{P^Y}\frac{P_\parallel^B}{P^B}$ is ≈ 0.999 in the Run13 experiment. The measured double helicity asymmetry becomes

$$A_{LL}^{\rm Measured} \approx \frac{1}{P^Y}\frac{1}{P^B}(P_\parallel^Y P_\parallel^B A_{LL} + P_\perp^Y P_\perp^B A_{TT}) \quad (1)$$

$$\approx 0.999 A_{LL} + O(10^{-3}) A_{TT} \quad (2)$$

where Y and B represent two colliding beams, and A_{TT} is the double transverse spin asymmetry. This analysis suppressed the systematic error of A_{TT} term to $O(10^{-3})$. A_{LL} measurements have been done up to $O(10^{-4})$ so far[2)], and $O(10^{-3})A_{TT}$ is orders of magnitude smaller than 10^{-4}.[3)] Therefore, $P_\perp$ does not significantly contribute to systematic error in A_{LL} measurements in Run13.

References
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2) A. Adare et al.:Phys. Rev. D 90, 012007 (2014)
3) K. Boyle: AIP Conf. Proc. 915,335 (2007)

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